The VGOS TWIN Radio Telescope TTW2 at Wettzell

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Abstract The southern Wettzell antenna Ws of the TWIN Radio Telescope Wettzell (TTW), which is compliant with the VLBI Global Observing System (VGOS), is equipped with the Elevenfeed, which offers a continuous frequency range from 2 GHz — 14 GHz. We will present the status of the broadband receiving system and the data acquisition systems installed at the Ws antenna (TTW2) of the Wettzell Observatory. Additionally, the future plans for both antennas of the TWIN radio telescopes Wettzell will be presented.

Keywords TWIN Radio Telescopes Wettzell, Elevenfeed, ring focus antenna, first results

Fig. 1 TWIN radio telescopes TTW1 and TTW2.

1 Introduction

The Wettzell TWIN radio telescopes, with a diameter of 13.2 meters, are based on the ring focus reflector principle. The antenna design was developed in close cooperation with Vertex Antennentechnik GmbH in Duisburg, Germany, the MIRAD Microwave AG in Switzerland, and the Geodetic Observatory Wettzell (GOW).

The initial idea to use such a type of antenna design is the general specification of the International VLBI Service for Geodesy and Astrometry (IVS) for the new generation of VGOS antennas, which is described in the reports about VLBI2010 [1]. The goal was to find a very agile antenna system which had a relatively small main reflector of about 12 meters with a high system performance over a frequency range from 2 to 14 GHz or even more. In the year 2011, BKG decided to buy a newly developed feed horn from Professor Kildal, the "Elevenfeed", as the specifications showed it to be the best candidate for the antenna type at Wettzell.

2 The VGOS Ring Focus Antenna TTW2 at Wettzell

The ring focus design was not quite familiar for use as a receiving system in radio astronomy, but it was selected for the TWIN radio telescopes Wettzell because of its performance parameters (see Figure 1). It has advantages for broadband feed horns, such as the Elevenfeed, which usually have a wider flare angle of 65° compared to traditional feeds in geodetic VLBI, such as the existing Radio Telescope Wettzell (RTW), which

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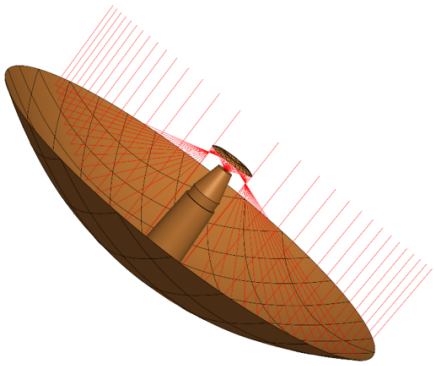

Fig. 2 Ring focus principle (courtesy of Vertex Antennentechnik GmbH).

has a Cassegrain design (22°). The shape of the main reflector of this design is geometrically generated by the offset section of a parabola at the focus line which is rotated at the antenna's axis of symmetry. The result is a main reflector that creates a ring-shaped first focus line in front of the subreflector. Figure 2 illustrates the optical path of rays for such a ring focus design, as it was originally designed. The advantage of this configuration is that all microwaves from the sensitive parts of the main reflector area are focused to the most sensitive region of the feed system. This will enhance the antenna efficiency and minimize backward reflections at the subreflector. But because of this high efficiency, the antenna system has also to deal with higher spillover effects.

3 The Elevenfeed of the TTW2

The development of the Elevenfeed began at the Chalmers University in Gothenburg in Sweden in the early years of the 21st century. It is a broadband feed with a fixed phase center at the ground plate (see Figure 3). The Geodetic Observatory Wettzell (GOW) ordered a newly built version of this feed that is able to operate at a cryogenic temperature from Omnisys Instruments in Sweden at the end of 2011. The new design offered a better performance at higher frequencies. Unfortunately, the improved version had a worse system temperature, which reduced the benefits of the higher efficiencies. Therefore, some adaptation had to be made, and after several iteration steps, it was possible to solve the issues within the last three years [2].

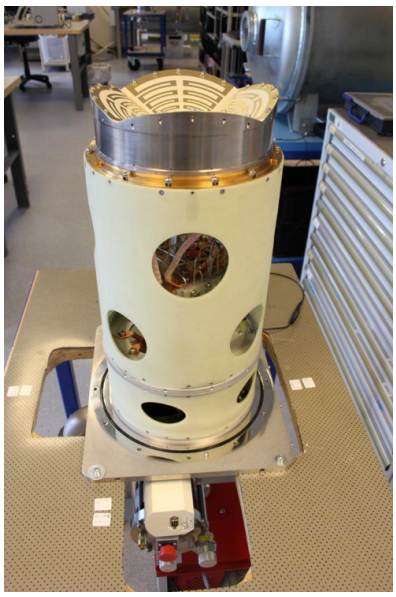

Fig. 3 Elevenfeed front-end (courtesy of Omnisys Instruments).

After a successful factory acceptance test at Omnisys Instruments in Gothenburg [3], the front-end of the Elevenfeed was delivered to the GOW in October 2014. Additional tests were performed at the GOW. The front-end system operates smoothly and reliably. In January 2015, a measurement of the complete set of patterns was done in an anechoic chamber at MIRAD AG to get the receiving parameters for an antenna simulation. The test results of the simulation were encouraging, showing efficiencies up to 70% over the whole bandwidth for the used antenna system [4].

Additionally, the measured cross polarization discrimination was roughly 20 dB with some spikes up to 15 dB in horizontal and vertical polarization, which is also a very good result. The measurement of the receiver temperature, which was done at Wettzell using an absorber and the cold sky, showed a T_{rec} of 20 to 25 K almost over the whole frequency range of 2 to 14 GHz.

A new feed cone to mount the Elevenfeed into the antenna was developed by MIRAD AG to enable an easier installation of the feed. An internal rail system supports the mounting of the feed into the feed cone to simplify the feed handling for the personnel doing maintenance. This is advantageous for maintaining the cold head. Furthermore, special attention was laid on

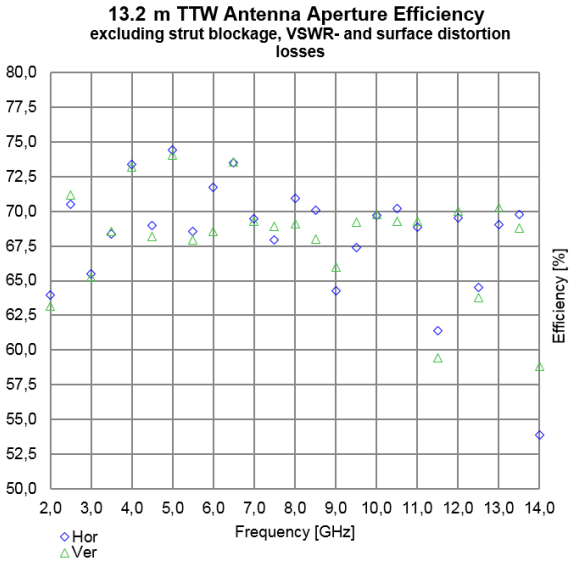

Fig. 4 Calculated aperture efficiency of TTW2.

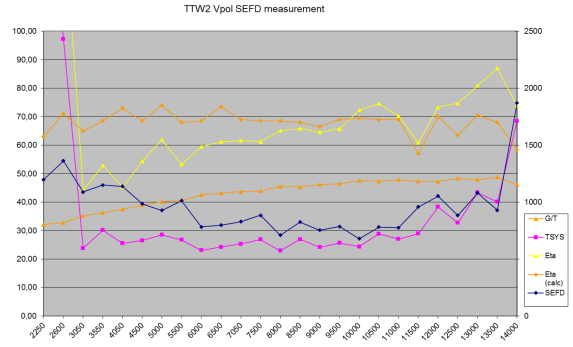

Fig. 5 SEFD, T_{sys}, and Eta measurements.

avoiding icing at the foil window to prevent a ring of ice on the window at low environmental temperatures. For this purpose, a feed blower was installed to blow warm air to the front of the feed window when low outside temperatures and high humidity are detected.

4 Final Test and Measurement Results at the Antenna TTW2

In February 2016, some measurements with radio stars (Cassiopeia A and Taurus A) showed a really good performance for the System Equivalent Flux Density (SEFD), which results in a good system temperature

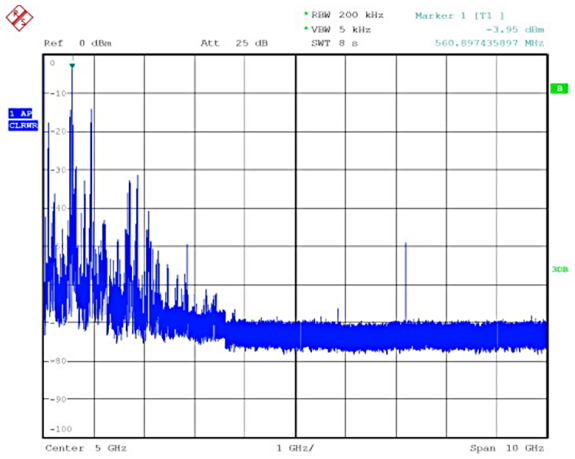

Fig. 6 Spectrum of the horizontal output signal.

and efficiency (see Figure 5). The measurement values at lower and higher frequencies are distorted by Radio Frequency Interference (RFI) from local and extraterrestrial radio transmitters. Therefore, further investigations must be made to get the final performance parameters.

The broadband capability of the feed is as good as modeled. Even at frequencies above 12 GHz a reasonable system performance at all measurements is given. Unfortunately, the lower end of the frequency range is at about 500 MHz, which leads to a high RFI level due to terrestrial TV stations (see Figure 6 at 560 MHz). To avoid a saturation of the post amplifiers, an additional high pass filter was mounted at the LNA outputs.

5 The New Wettzell Phase Calibration Unit

For the use in both TWIN radio telescopes, a new phase calibration (pcal) unit was designed (see Figure 7). The phase calibration box contains all necessary post amplifiers for all bands and polarizations. The noise calibration sources and power dividers for the T_{sys} measurement are included there as well. The pcal tones are adjustable to different intervals and can be locked to different reference frequencies (5 MHz, 10 MHz, and 100 MHz). The box is designed very compactly and is temperature-stabilized.

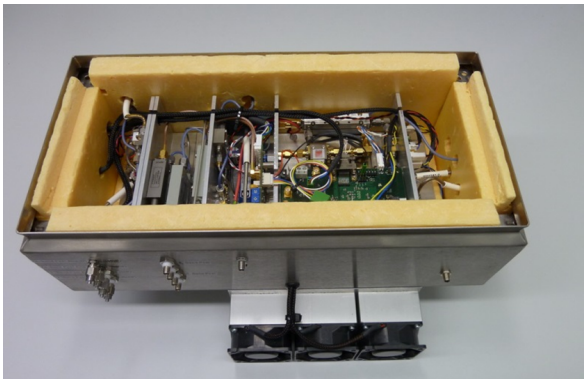

Fig. 7 Wettzell Phase Calibration Unit.

6 Conclusion and Outlook

The TWIN radio telescope TTW2 at the Wettzell observatory is equipped with the broadband Elevenfeed. The telescope and equipment required is operational for VGOS tests. Initial delays were caused by different issues during the development of the feed and feed mounting. Nevertheless, the performance measurements by the GOW and by MIRAD AG are in good compliance with simulations for all system parameters.

The overall system performance was obtained using reference radio sources at the beginning of this year. The first results presented are promising. After the installation of the new broadband down converter, some first VGOS tests with other stations were planned and already executed while this paper is being published.

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